warmth which accompanies it, and that in the same way they are attracted by the light of a candle placed close to the sides of the *formicarium;* the glass being warmed and becoming a source of radiant heat. The elaborate experiments of Sir John Lubbock, showing that ants preferred the red end of the spectrum and avoided the violet end, are all explained by their preference for the greater warmth accompanying the red rays, though he also thinks they dislike the effect of the chemical rays. His general conclusion is, that there is no evidence that they distinguish colour or prefer one colour to another, but that they always prefer warmth, and dislike the action of the chemical rays of light, while to light itself they have no objection whatever.

Mr. White reproduces from the *Proceedings of the Linnean Society* for 1861 a remarkable account of some Australian ants burying their dead in a methodical manner strongly resembling our funerals, and supports it by some curious observations of his own. In one of his newly procured nests there were many dead ants, which were carried up from below and placed against the glass. Three small card trays containing honey for the ants were placed in the *formicarium*, but instead of eating the honey the trays were used as cemeteries, and in two days 140 dead ants were placed in one tray and 180 in each of the others. In another case he observed the ants burying the dead in subterranean cemeteries, the bodies being covered with earth and the passage leading to the vault being stopped up.

A good account is given of the various creatures found in ants' nests, such as the crustacean *Platyarthrus Hoffmanseggii*, the various species of beetles, some of which are never found elsewhere, and seem to depend on the ants for their subsistence, and the aphides which the ants actually breed for their own use just as we do cattle. Some ants have small colonies of other ants domiciled with them, apparently as guests or lodgers, while others capture the pupæ of distinct species and bring them up to work for them like veritable slaves. This extraordinary habit of slave-making is fully described in two very interesting chapters, and Mr. White is one of the few Englishmen who have been so fortunate as to witness the slave-hunters at their work.

We cannot better illustrate our author's style and his mode of viewing the subject of ant-economy than by quoting the passage in which he sums up the result of his observations and inquiries :—

"And now, surely enough has been said, ample evidence has been brought forward, my own personal testimony having been confirmed when necessary by the experience of others, to warrant me in earnestly demanding for my little clients a favourable verdict. When you bear in mind the self-devotion of the queen for the commonwealth ; the loyalty of her subjects, their affection towards their youthful charges, preserving as they do a happy medium between undue severity and over-indulgence ; their liberal system of education without the aid of privy councils and revised codes ; their plan of drainage, most effectual before boards of health and city corporations had ever been heard of ; their public works and national enterprises, planned and executed with the most surprising promptitude, uncontrolled by parliamentary committees, orders in council, and circumlocution offices ; their social institutions, their provident clubs and savings banks, gathering as they do their meat in the summer—the continental and foreign ants grain and honey, the British ants their aphides for future use ; when you bear in mind their perseverance under difficulties, that no poor-house or assessment committee or sanitary authorities are needed, for all live as brethren, all sympathise with each other in trouble and difficulty, and share everything in common as members of the same happy family, 'he that gathers much having nothing over, and he that gathers little having no lack ;' when you remember their habits of early rising, of cleanliness, of moderation, of economy, of temperance, their love of fresh air, their skill and industry in their many trades, the magnificent scale on which they construct their houses ; their language, which, though more difficult to acquire than Chinese, yet is to them so intelligible that there are no misunderstandings, all speaking it fluently, and by means of its mysterious agency communicating their ideas to each other ; when you recall how they carry out concerted plans thoroughly, noiselessly, uninterruptedly, not resting till their work be finished, animated by one spirit, pursuing thus the end, fulfilling thus the law of their brief existence—you must allow that surely this 'little people' are 'exceeding wise.'"

Though somewhat anthropomorphic and highly coloured, this passage brings before us in a striking manner the many marvellous characteristics of the habits and instincts of ants, and also serves to show the thorough and enthusiastic study which the writer has bestowed upon them.

The book is well illustrated with numerous woodcuts from original drawings ; and in an appendix is given a complete list of British ants with careful descriptions of all the species, forty-one in number. It will therefore be of great assistance to any entomologist wishing to commence the study of our native ants ; while as an interesting volume for the general reader, or as a gift-book for children with a taste for natural history, it may be safely recommended as among the very best of its kind.

ALFRED R. WALLACE

LETTERS TO THE EDITOR

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts. No notice is taken of anonymous communications.*

[*The Editor urgently requests correspondents to keep their letters as short as possible. The pressure on his space is so great that it is impossible otherwise to insure the appearance even of communications containing interesting and novel facts.*]

The Matter of Space

IN his letter on this subject in NATURE (vol. xxviii. p. 148), Prof. Morris strikes, I believe, a keynote of very great interest in the general theory of motion, when he lays it down as a primary principle that all motion naturally tends to attain a condition of stationariness in which, though it still constantly springs or swings hither and thither, it is yet permanently localised in some fixed field, contained within definite inclosing boundaries.

Singular as the law appears that motions, bound and hemmed in as we see them everywhere around us, are only ostensibly confined to their spheres by combinations of directed forces, while they are really inclosed in them by a governing principle in matter which constantly models its directed courses either by continuous or by interrupted stages into forms of stationariness ; and strange as the statement sounds, that all matter thus tends constantly to form *in situ* veritable universes[1] externally re-

[1] A pamphlet, "The Universe, or the Science of the Twentieth Century," maintaining exactly this microcosmical theory (by what course of reasoning arrived at I cannot guess), reached me not long ago from a writer, Mr. John Tate of Portadown, in Ireland, with another ("A New Theory of Electricity,") describing electricity as a kind of twisting power, both of which, from the independent practicality of their treatment, seem to have been entirely prompted and suggested to the author by exact meditative study and by clear original reflections.

posing and quiescent, and internally passive, neutral, and indifferent to all surrounding material universes, yet I am disposed to concur with Prof. Morris in his emphatic enunciation and very appropriate and varied illustrations of this law, because the idea of established boundaries, prescribing fixed terms and limits to motor-vigour's local actions, has, in an investigation of the principles of thermodynamics which lately occupied me, already presented itself to me as an indispensable foundation for a theory of heat, in which temperature was identified with motor-couple's dual power of dispensing motor-vigour between ordinary and ether masses, partly by opposing undulatory, and partly by contending diffusive motions of ether's and gross-matter's aërilian parts.

Easily as that theory lent itself in other respects to a deductive establishment of the laws of heat, it yet stumbled abruptly upon this blank presumption, or frowning precipice, *of how* boundaries of the kind (to such forms of aërilian action) come to be established and imposed between ether and gross matter, as well as between material bodies generally, wherever superficial contact between their substances takes place?

Granting indeed, provisionally, that we may freely accept Prof. Morris's somewhat too simple, and in fitness for its purpose much too meagre and unassuming supposition (which I should also say that he errs in describing me at the beginning of his letter as being just as willing and contented to accept and conform to as he is himself), that "particles of ponderable matter consist of aggregations of ethereal substance," or that "ether is a substance whose condensation yields particled matter," it would then be making a step of inference which would neither be a positively ungrounded one, nor (supposing that nature's system were really such a simple one as this hypothesis assumes) at all a likely one to conduct us to any embarrassing or perplexing consequences, to describe the "excessively disintegrated matter" which in his *aperçu* of the retinues of space "replaces ether," as ordinary matter in a "fourth state" of attenuation; because we would immediately reflect that the boundaries between the solid, liquid, and vaporous forms of such a multistructured substance as ethrogenous matter would then be, are themselves well known to be the seats of a certain diffusive and undulatory struggle and balanced equipoise, the real nature of which, beyond what is known of its laws of relation to pressure, heat, and temperature, cannot be accurately described. The fact that temperature and tension regulate it does, indeed, assimilate it to the similar dual balance of motor-couple's diffusive and undulatory actions at the borders between ether and ordinary matter which I found to be indispensable as a first starting-ground for basing a mechanical theory of temperature, heat, and entropy on mathematical properties of motor-couples; and our ignorance of how the boundaries are established in each case is not only no greater, but it actually appears to be of precisely the same nature and description in one of these cases as in another.

The parts which collision and vibration play in distributing motor-vigour in solids, liquids, gases, and in ether, are abundantly well-instanced and described in Prof. Morris's letter; and it again affords me extreme gratification to note the exact parallelism which his views present with those furnished by a systematic and not perhaps altogether unmathematical treatment of the subject which I have pursued, if, as I surmise, undulation and diffusion are kinds of motor-action (both active in a motor-couple) of such primitive simplicity of construction in their agitational or motor-type, that, in virtue of their elementary mathematical character, one single mechanical explanation really suffices for and applies with equal exactitude to all those instances of material conflict just considered, which occur at the boundaries between the several gross and ethereal states of matter.

But both physical and mathematical considerations have besides this led me to suppose, as I trust that they may also in the end influence Prof. Morris's decision, that the title of the "fourth state" of matter which we might thus quite fairly at first sight and provisionally apply to ether, is in the all-essential meaning of the words an undeniable misnomer; because mutual conversion of the two substances composing the first three and the last of the forms in question one into the other is *bonâ fide* shown by the clearest evidence of experience, and equally by theoretical proofs based on the two substances' motor relations, to be, even more certainly than making gold out of copper, an impossible physical proceeding. With such plain reasons as I will try briefly to produce for pronouncing ether and ordinary matter to be perfectly distinct and totally untransmutable fellow-occupants of space, it is really more consistent with simple fact, and a more precise and correct use of language, to speak of ether as "matter of the second class" or of the second grade or order, than it would be to call it either dubiously matter "in a fourth form," or to give it the still more erroneous title of a "fourth state of ordinary matter."

While, in fact, we know innumerable chemical and physical forces capable of altering to any give-and-take extent the boundaries between liquids and their vapours, between similar and dissimilar solids and liquids, and like and unlike gases and molecules, so as to change entirely all their physical and chemical states, or groupings, yet no force of art or nature can make any portion of gross matter change its weight by condensation or escape of ether. Even chemistry, to whose reactions Prof. Morris assigns the greatest power of altering molecular groupings, although tested in this direction with the delicacy of a vacuum-balance in Mr. Crookes' researches, has been found to be powerless to do so. It is true that its reactions only employ the sedatory tendency of motion in order to produce new groupings, and the electric current, which first disclosed the existence of the elements sodium and potassium, and whose arc of light gives us glimpses of chemical dissociations scarcely less complete than those detected by the spectroscope in the sun, overcomes and reverses the power of chemical affinity to form combinations in this way more effectually than any other force, and breaks up all chemistry's compound productions more completely than any other force can do. Yet, while no dissipation of weight of ordinary materials by electric currents has yet been detected, it is just as certain that ponderable matter has never yet to our knowledge gained or increased in weight in virtue of the exertion of any possible chemical affinity which it may have for ether, although this affinity, if it exists, must yet be of extraordinary strength, since it can successfully resist every effort that has yet been made to loosen it! Either imponderability of ether or immutability of its boundaries of junction with gross matter, or both of these together, must therefore be assumed to account for the sum of this experience; and whichever of the alternatives we are led to choose, distinctly differentiates the two substances from each other as regards this particular character of mutual convertibility of substance, for no known ordinary matter arising from ether's condensation is imponderable, or, on the other hand, if ether has weight, experience still shows that no condensation of it into ponderable ordinary matter is possible.

Another conspicuous peculiarity of ether consists in a special independence between its motor-vigour and that of ordinary matter, of which instances of the plainest proof are afforded by Doppler's theory and by the theory of the aberration of light. The motions of ether in an ether-replenished field are not in the least degree affected by the directed motion across it of a mass of ordinary matter, just as a perfectly smooth anchor would leave no permanent agitation whatever behind it in water or liquid inwardly and outwardly as smooth as itself, through which it takes its way. It is only by such a passing body's aërilian or undirected motions that ether can be disturbed, and with those it harmonises or collides, mutually receiving from and imparting to the body it so touches motor-vigour (which may either take the form of actual heat or of stresses in the ponderable body) by the primitive aërilian processes of wave-impact and diffusion-blows of the two substances at the boundary between them. With the absence of these (if we could imagine the privation to exist) the bodily or directed motion of the two substances, like those of a smooth anchor swinging in a stream of frictionless water, would all the while be wholly unaffected by, indifferent to, and independent of each other. The ether therefore stands in such motor-relations to gross matter that the two can only exchange motor-vigour with each other by means of the aërilian impulses of their touching parts.

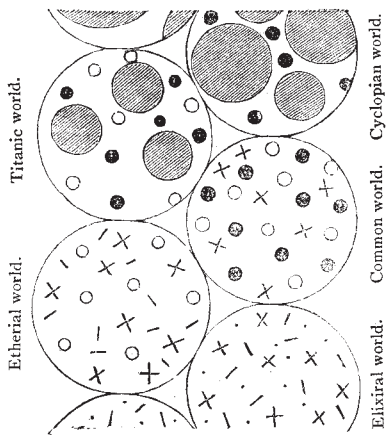
Now this theory of ethereal action, suggested to me by an accidental consideration of the well-known mathematical equation of stationary motion, which was at once seen to furnish, on closer examination, a very consistent interpretation of the second law of thermodynamics, and of its several thermal quantities, led me to describe in my former letter (NATURE, vol. xxvii. pp. 458 and 504) some of the necessary postulates or maxims of the new theory in its integrity of fitting enunciation for such applications.

If the mutual motor-relations between ether and gross matter are indeed (as I have very full grounds for confident assurance) of the extraordinary nature and description there set forth, there seems to be no room to pause or to waver and hesitate over nicely raised but unavailing protests of prejudice and predilection in

their contemplation. In the ocean of universal ether are described baric points and masses "nestling" together, and "nestled" in their attendant or "bound" ether ones, which themselves cluster or "nestle" like atmospheres about them. Each such ethrobaric assemblage is a universe, when in repose, independently of the unbound and unbounded ether-ocean, which alone stands aloof as a universe by itself. And among all these the instantaneous as well as the hare-and-tortoise-footed paces of time take effect, and swiftly or gradually, along with many other actions, cluster the island-masses together more and more.

By what rigid cord the clustering tendency to establish certain boundaries is controlled, what struggle for existence gave their present forms to elements and suns and planets and to the ether atmospheres belonging to them, appears to be a question of just the same cyclopean vastness, and in some measure of the same description, as that which presents itself to our inquiries in animated nature. And since it is exactly this ruling rein which sets the boundaries to bodies, no harder problem can perhaps be contemplated than that of defining how, at a point of contact, the boundary between two dissimilar physical bodies is preserved.

In particular the contact of our physical world of ethrobaric alliances with universal ether, where to us complete and perpetual silence reigns, and in the other direction of inconceivable hugeness instead of smallness of integration, common ethrobaric matter's contact with a universe just as conservative as ether is of suns' and galaxies' corporeal struggles, but in this case beyond the ken and vision of the most gigantic telescopes, are probably *par excellence* the seats of strife and contest of all or at least of many more orders and successive grades of matter than take part in



Chain of Matter's Motor-actions.

those between spheres of ponderable matter and their ether atmospheres, or between the alliances of these that constitute our world of physics. The arena of graphic space for all these universes is the same, and there appears to be no difference in their geometry but this, that the scales of magnitude of their disintegral parts proceed *by absolute infinities* in their proportions to each other. But this difference is of such an essentially strict mathematical kind, corresponding to precisely equivalent analytical and geometrical relations wherewith, sooner or later, there can be very little question that it will be possible to express it, that the "excessive disintegration" contemplated by Prof. Morris is really one of infinite disintegration. And what it is which sets bounds to the universal ether by itself, so as to make it a third party to the exchanges of motor-vigour between the bound intergroupings of gravitating and ether-matter (and perhaps a shaping and forming link of these to the larger-statured universe out of reach of telescopic vision), unless it is a substance of more infinite disintegration still than ether, an elixir of ether as we may style it, shaping and forming both that ether itself and its alliances with baric matter, it would certainly be exceedingly difficult to say.

Thus in the above figure it will be seen how boundless graphic space (denoted by the inclosing circles) may all be filled and occupied at the same time by a continuous chain of matter-triads consisting of matter in innumerable different untransmutable grades of fineness of disintegration, of which only three adjoining ones are physically concerned together in any one of the linked world-systems of the chain's horizons, in producing that world-system's or horizon's natural phenomena. The functions of ether and "elixir," for example, can be traced in the figure in giving inanimate nature its form and stature, and in producing its physical phenomena in the world of ordinary or common matter; and that of common matter and ether, again, in doing the same in the larger-statured or "Titanic" world; and so on for worlds of vaster, or *per contra* of finer, textures than our own.

But as I reasoned at some length to show in my former letter, a proper branch of geometry must be specially developed and explored to describe even the space-relations of these several material horizons to each other clearly; and there is besides this the part which time plays in the control and evolution of motor-actions by their transmission from one horizon to another, to be investigated and considered, of which it can hardly be foreseen that the research will be easier, although sure in due course to be prosecuted successfully, than the investigation of the geometrical relations.

It cannot therefore be expected that the beginnings of physical phenomena like those of light, heat, magnetism, and electricity (and of chemical phenomena in addition), due to motor-vigours of imponderable substance, should all be easy to fathom and unveil at once. But very grateful reception and approval must yet be freely and fairly accorded in the meanwhile to such able and successful attempts as Prof. Morris makes and proffers in his letters to unravel them, as being unquestionably of very great present, and of incalculably greater prospective use and value to assist in pointing out the right road and in paving the way towards their final elucidation. A. S. HERSCHEL

Newcastle-on-Tyne, June 25

P.S.—A little more inquiry shows me that it is not essentially in absolute size, *but in volume-density* of the integrant parts, that "titanic," "ethereal," and other kinds of matter differ by infinity, and by infinity beyond infinity, from common ponderable matter. An integrant part or "atom" of common matter, for instance, becomes by infinite expansion[1] an infinite-sized network of extremely far-separated (countlessly numerous) titanic matter-atoms, whose expansion will have rendered them all ordinary substance and will have raised all their internal constituent atomic parts, like themselves, one grade in attenuation; while the original common-matter atom itself will not in the least degree lose its individuality by its enlargement of stature, but will become at the same time an infinitely large common-matter, and an infinitely large ether-atom. The titanic members also, although an infinite-fold larger and less dense than titanic atoms of a mean size, do not lose their proper relativities with their normal-sized fellows, although they acquire a new consociation by assumption of a lower density, with atoms of common matter; so that exchange of energy or of motor-vigour by the ordinary processes of diffusion and wave-motion can in these circumstances subsist between ordinary and titanic matter on a footing of equality. And it is the same, in the common-matter atom's state of ethereal hyper-attenuation for its exchanges of energy and momentum with ether-atoms of the next higher order *of magnitude* than those which we call mean-sized.

To how many successive grades such hyper-attenuation may be carried there is no actual evidence to show, but in the system's theory itself there is nothing to restrict it. We must only remember that each successive grade is an infinite step onwards in expansion or contraction; and since common-matter's atoms or first integrant parts are known (as Sir W. Thomson has most clearly shown, NATURE, vol. xxviii. pp. 203, 250, 274) to be of finite, though of excessively small dimensions, their hyper-attenuated forms are of an immensity whose size is mathematically infinite, and we cannot therefore point to them. A single common atom's transition-form to ether-density pervades all visible space. Its transition-form to "titanic" density occupies no visible space at all, and is graphically a material point, although entropically it is infinitely composite; and the motions of each of these forms are absolutely invisible to us, but not less real and effective in their contributions of motor vigour to ordinary matter at the confines of its contact with ether megaspheres, and with titan micro-points in graphic space.

[1] If time is allowed any homogeneous assemblage of matter-atoms to equalise their temperatures, the whole assemblage and its parts, consisting of common and of remoter matter-grades, will, I conceive, all have one and the same common rate of volume expansion (as described above) to whatever extent, finite or infinite, the expansion or contraction is continued at one settled temperature.

However many times material atoms may be hyper-attenuated or condensed, their substance no doubt retains its original material *status*, although removed by numbers of grades or orders of attenuation from it to which the mathematical principles of the theory assign no limit; and boundless space is thus strewn at once with a grade of common-matter atoms, which in their original *status* may have properly belonged to any other grade of unknown remoteness. But this fixity of matter's original grades of size and density with only infinite insulations from other grades, is not more notable than the unrotativeness or fixed directions of some coordinate axes of mechanical motions in space which does not prevent the motions from being just as perfectly describable by the selection of any other equally fixed ones. We are in the same way unable to say by how many revolutions the hands of a clock have reached a certain position on its dial, unless we examine and properly employ to estimate it the state of wear and attrition of the wheel-work of the clock's driving train, or unless we know the number of times that the clock had been wound up.

The solution of some very bewildering physical questions is offered by this hypothesis[1] when we reflect, as I have before endeavoured to explain, that the expansions here considered are all of them variations of a quantity ϕ (or "entropy" of a homogeneous body at the same temperature throughout), which, by its mathematical description, is obviously the ratio index of a describing point's place upon a hyperbola, and which therefore passes continuously through an endless series of values 0 and ∞ (which revisit each other in graphic space, just as a circle-radius revisits its former place after every passage through four successive right angles), while the describing point pursues the curve continuously.

There is enough evidence in geometry to show that this hyperbolic variable of position, and the angular one on the hyperbola's auxiliary circle of a certain configurated point on that circle, cannot pursue their geometrically configurated course together through more than a quadrant of the circle and hyperbola from the two curves' common apex without violating the axioms of ordinary geometry. Thus it is clear that in the transition state of the measure ϕ through infinity from one "grade" of a mass's state of attenuation to another, there is needed a new law of geometry (or at least of continuous material motion) allowing a new pair of tracing-points supplanting the disused former pair at each dead-point of the two curves, to describe a new quadrant of the hyperbola and of its auxiliary circle from that point, with a constant geometrical configuration to each other without violating geometrical axioms.

This transition law and the nature of the configuration which it frees from geometrical contradictions while giving it continuous validity round the whole circuit of the circle and hyperbola together, is so exactly what has just been described of the nature of material points' or of physical integrant-parts' compositeness while still remaining points in their motor properties, that almost all reason for doubt and question seems to be excluded that it is the sought-for law and mode of motor connection between θ and ϕ (or angle- and entropy-position of a point or homogeneous body), which links universal heat-motion of matter to all those other, no doubt therefrom derivable but otherwise unaccountable descriptions of matter's motions which we see in physics.

[1] In particular, as will be easily gathered from the above brief comments, of the law of dissipation or of a fixed tendency to gradual reduction and to universal uniform diffusion of all forms of energy *in a given link* of matter's grades in one common form of the energy of heat, or of the work of entropy-expansion.

On Lord Rayleigh's Dark Plane

IN NATURE, vol. xxviii. p. 139, was printed a communication from Lord Rayleigh to the Royal Society on the subject of the dark plane which is seen above hot bodies in dusty and illuminated air, and which had long been used by Tyndall, and after him by science teachers generally, as an illustration of the fact that light which does not enter the eye cannot be seen.

It had never occurred to me to doubt the validity of the commonly-received explanation of the dust-free space, viz. that the dust in the dark region had been either burnt up or dried up by contact with the hot body, and I was struck and greatly interested in the definite character of the phenomenon as described by Lord Rayleigh in your pages, and in his conclusive shattering of the old explanation by the simple device of using a cold body instead of a hot, and so getting a down-streaming dust-free space instead of an up-streaming.

I was however quite unable to accept Lord Rayleigh's very tentative hypothesis that the curvature of the stream-lines and consequent centrifugal actions might possibly account for the phenomenon, nor do I imagine that he himself ever regarded this as anything more than a guess thrown out for want of a better.

I mentioned the matter to Mr. J. W. Clark, whose services as Demonstrator I have lately had the good fortune to secure, and he proceeded to make a few simple experiments with a view first of repeating the observation, and next of testing an electrical hypothesis which suggested itself.

The hypothesis is one that has failed to verify itself, but it may be just worth stating. The difference of temperature between the solid and the air causes convection currents, the air thus made to stream over the surface of the solid electrifies itself by friction, and the dust particles are expelled from the electrified air.

We were early led to doubt whether the insignificant amount of friction which alone was acting in some cases could possibly produce the effect; and in fact it was soon found that though electrification modified the phenomenon it pretty certainly did not cause it.

A doubt then arose whether the space was actually dust free or only optically so; whether anything like mirage due to unequal densities could account for the darkness. These ideas, however, would not bear consideration, and we soon convinced ourselves that the region is really transparent air free from dust, though its extreme sharpness and blackness render it difficult at times to refrain from thinking of it as a black opaque film.

Irregular dark striæ obviously allied to the regular dark plane are to be perpetually observed in any dusty air disturbed by convection currents; and nothing but the want of the necessary illumination prevents our commonly observing what must be one of the most universal appearances, viz. dust-free regions streaming from every solid body.

We are now pretty well convinced that differences of temperature have nothing to do with the real nature of the phenomenon; *we find that solid bodies have sharply-defined dust-free coats or films of uniform thickness always surrounding them*, and that these coats can be continually taken off them, and as continually renewed, by any current of air. The slightest elevation of temperature of the solid causes its dark coat to stream upwards; the slightest depression of temperature below that of the atmosphere causes the coat to stream downwards; but the coat is there all the time, independent of convection currents, though I believe it gets thicker as the body gets warmer. *Why* the air near a solid is free from dust we are not prepared to say.

A few of our earlier experiments might readily enough have suggested the old exploded explanation that the smoke was either burnt up or dried up or otherwise temporarily rendered invisible by heat. Take for instance a long piece of ordinary quill glass tubing; blow it half full of tobacco-smoke, and hold it horizontally in a beam of light. The first thing to notice is the curious way the end of the stream of smoke draws out to a point with a sharply defined edge, and how it falls about inside the tube when the tube is rotated. Next warm a part of the tube gently: a space clear of smoke at once appears and widens. Next heat the tube in the flame of a Bunsen and blow smoke gently and continually through it: the smoke narrows down to a mere thread as it passes the hot place, or it may disappear altogether in a pointed cone; but it reappears on the other side of the hot place, and it issues from the end of the tube.

Our experiments have been mostly conducted in a glazed cigar-box with one or more horizontal copper rods passing into it through insulating glass tubes, the ends of the rods carrying binding-screws into which could be clamped scraps of sheet copper of various shapes. The illumination was either sunlight or an oxyhydrogen lamp, or more usually, and far the most conveniently, a Serrin arc-lamp in its lantern, fed by a secondary battery. The smoke employed was nearly always tobacco, for we soon satisfied ourselves that the nature of the smoke or dust did not affect the essence of the phenomenon, and we consequently used that which was the easiest and for which the implements were always at hand. Sal-ammoniac was, however, occasionally used instead.

It was wholly unnecessary to heat the rod in order to start the dark up-current, for if it is not infinitesimally warmer than the air to begin with, the beam of light will warm it sufficiently in an instant. Still the rods can be heated by a lamp outside the